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NASA Shuttle Lightning Research:

OBSERVATIONS OF NOCTURNAL THUNDERSTORMS AND LIGHTNING DISPLAYS AS SEEN DURING RECENT SPACE SHUTTLE MISSIONS

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1. BACKGROUND

NASA MSFC lightning researchers have used the high altitude U-2 aircraft since 1978 and the newer version of the U-2 or ER-2 aircraft (Figures 1A and 1B) to photograph and collect optical pulse waveforms and electronic signatures of lightning using an instrumented package. The instrumentation usually consist of an optical pulse detector, a slow and a fast antenna, and recording equipment, located either in the lower bay of the U-2 aircraft or in a pod located either on the wing or in the nose of the ER-2 aircraft. This instrumentation package was operated by the pilot as he flew over the top of selected thunderstorms complexes, while being vectored from the ground. Data from the early research flight programs (Vaughan, 1984) helped in the development of an instrumented (NOSL) (Vaughan, January 1985) which was flown on the early space shuttle missions of STS-2, -4, and -6. The hardware, a small hand held film camera and a sensor operated by the crew, were flown to photograph lightning and to collect electronic signatures of lightning from storms as seen from space. The main objective of the early U-2 aircraft and shuttle flights were to provide design criteria for use in the design of a geostationary satellite-borne optical lightning mapper instrument or a small simple orbiting satellite for monitoring mesoscale thunderstorms and their associated lightning.

Objectives of the early MSFC lightning research program in the beginning were to develop a better understanding of the optical and electrical characteristics of lightning and to investigate the relationship between storm electrification and other underlying and interrelated phenomena including the structure, dynamics, rain voume production, and evolution of thunderstorms and thunderstorm systems.

2. INTRODUCTION

Our present lightning research goals here at MSFC are now focused on understanding the behavior of lightning and the global distribution of lightning rather than characterizing the types of optical and electrical signals it produces. To achieve these goals a new shuttle lightning observational program called Mesoscale Lightning Experiment (MLE) began flying on STS-26 in 1988. This program is now directed toward using the low Earth orbiting shuttle as a platform to observe the global distribution of lightning and the behavior of lightning and/or other phenomena that might not be seen from the ground. This program concentrates on using the shuttle payload bay TV cameras when the crew members are asleep and/or at other times when the crew members are not available to make observations. Since the cameras can be operated from the ground, viewing time of targets of interest are longer and provide more data.

The shuttle MLE demonstrated that excellent data could be obtained using the payload bay TV cameras on STS-26, -30, -32, and -34 and the experiment will be flown on each shuttle mission when it can be conducted on a non interference basis. This experiment has continued to focus on obtaining additional measurements of lightning characteristics and create data for use in demonstrating observation simulations for future space-borne orbiting lightning mapping satellite systems. These flights are also providing criteria for use in the design of a proposed future experiment consisting of a spectrometer and camera which could be mounted in the mid-deck window area or mounted in a canister located outside in the payload bay. This instrumentation will be used to obtain video, optical pulse data, and spectroscopic signatures of lightning.

3. DISCUSSION

Figure 2 shows one of the more recent photographs of lightning as seen by the STS-55 crew members. This hand held camera photo, taken by Mission Specialist Charles Precourt, was captured using a 1 second exposure and ASA 1600 color film. Seen in the image are the lights of Mexico City and thunderstorms and lightning. The photo was taken under moonlight conditions thus allowing us to see the clouds and city lights. Figure 3 shows a daytime hand held camera photo of a large convective thunderstorm cell with it's large convective updrafts. This photo was taken using a 250 mm lens.

The most unusual type of lightning observed are the vertical discharges that were seen moving out from the top of a thunderstorm when we observed them while looking at the limb of the Earth with the shuttle's payload bay low-light-level TV cameras (Figure 4). These cameras with their low light level capability allow one to see the thin bright line above the limb of the Earth which is the airglow of the Earth's atmosphere and stars. We have seen the vertical type discharges from a number of developing large storm cells complexes as well as single cells that were observed over Africa, Australia, South America, and also in the United States. On the average, most of the vertical discharges appear to be at least 25 km in length based on shuttle's orbital position, star fields, etc., and the shuttle position from these events. Since most of the events that have been observed are located near the limb they appear to be vertical, however, they could be longer or shorter depending on whether they are coming toward or going away from the observer. Figure 5, a typical vertical lightning pulse, was seen to move out of the top of a thunderstorm located at approximately 7.5 degrees North Latitude, 4.0 degrees East Longitude during STS-31 mission and was about 2,000 km from the shuttle's position. The limb of the Earth, the tail of the shuttle, stars, and the numerous thunderstorms can be seen in this image. Figure 6 shows a number of other vertical type lightning events that have been observed. References 3, 4, 5 and 6 present some of the other types of information that have been obtained from this type of video data.

In the future we will be able to fly the proposed additional instruments in addition to the payload bay TV cameras to obtain additional optical pulse and spectroscopic signatures of the vertical type lightning.

Since these vertical events are interesting phenomena we are trying to develop theories which may explain them.

4. CONCLUSION

The shuttle video imagery now being obtained from the MLE observations is being analyzed for the frequency of lightning flashes, the length of lightning discharge within the cloud, and global estimates of lightning activity in storm systems that can be seen which are oblique from the shuttle's orbital track on a time-available basis. These shuttle type observations are continuing to provide information for developing data analysis techniques for use in future shuttle missions, data from the Earth Observation polar platforms, and Space Station Freedom.

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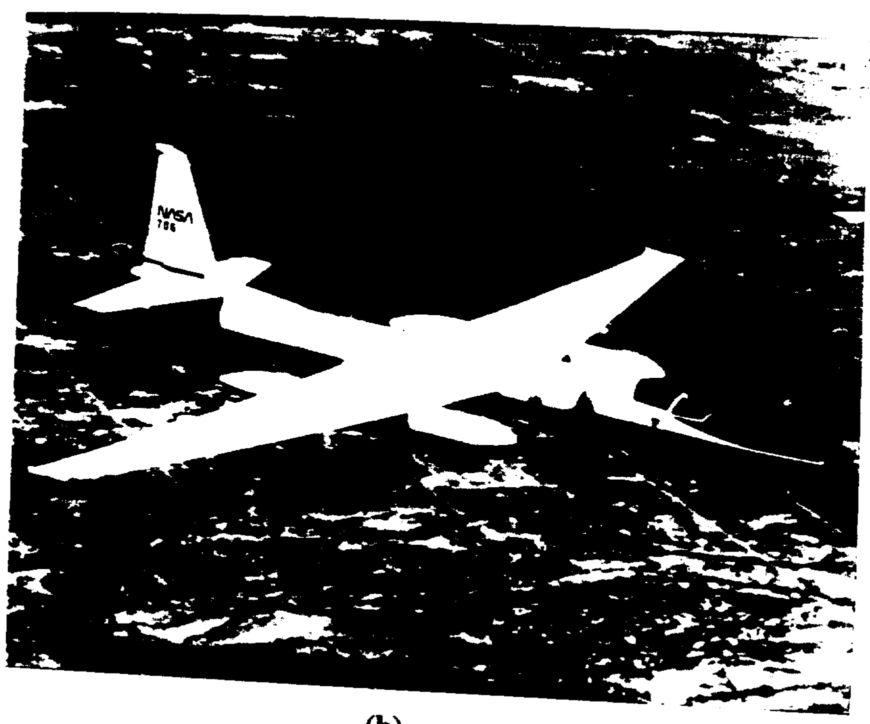
(a)



(b)

Fig. 1. NASA high-altitude aircraft used in lightning research programs. (a) U2; (b) ER2.

Fig. 2. Shuttle photograph of lightning using hand-held camera showing city lights, thunderstorms in clouds, and payload bay of shuttle illuminated by moonlight.

Fig. 3. Shuttle photograph of single storm cell using hand-held camera during daylight.

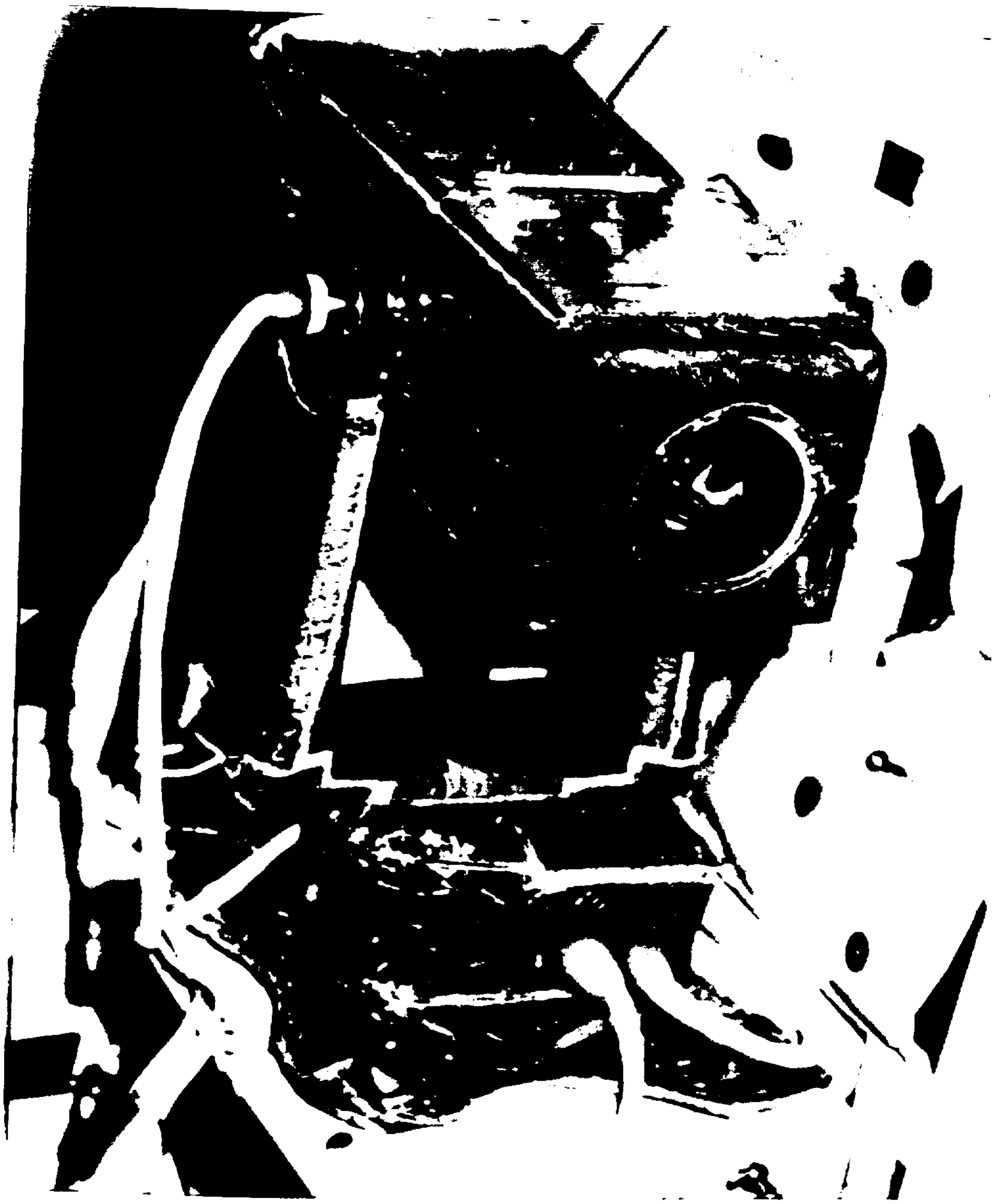


Fig. 4. Shuttle payload bay low-light-level TV camera.

Fig. 5. Vertical pulse of lightning as seen from a shuttle payload bay low-light-level TV camera.

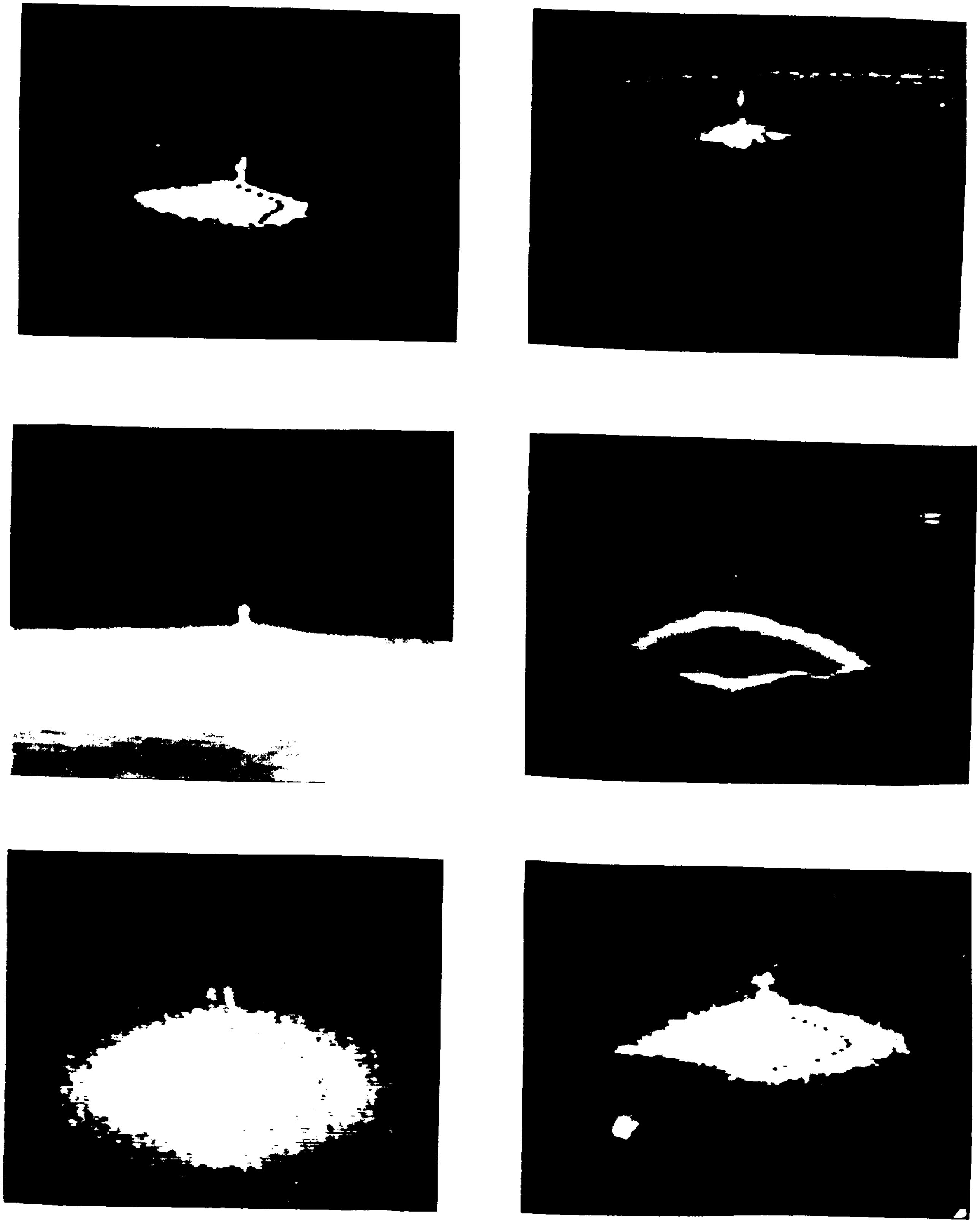


Fig. 6. Various types of vertical lightning as seen by a shuttle payload bay low-light-level TV camera.